

1st year results:

Global Flood Risk from Advanced Modeling and Remote Sensing in Collaboration with Google Earth Engine

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Why Study Floods

Flooding is the most common natural hazard worldwide
Floods impact 21 million people every year and affect the global GDP by \$96 billion

**Increases in frequency of river floods in Europe:
predicted to double in coming 3 decades**

Alfieri et al., 2015.

Knowledge gap

Most rivers experience flooding as seasonal discharge varies $\sim 2 - 3$ orders of magnitude

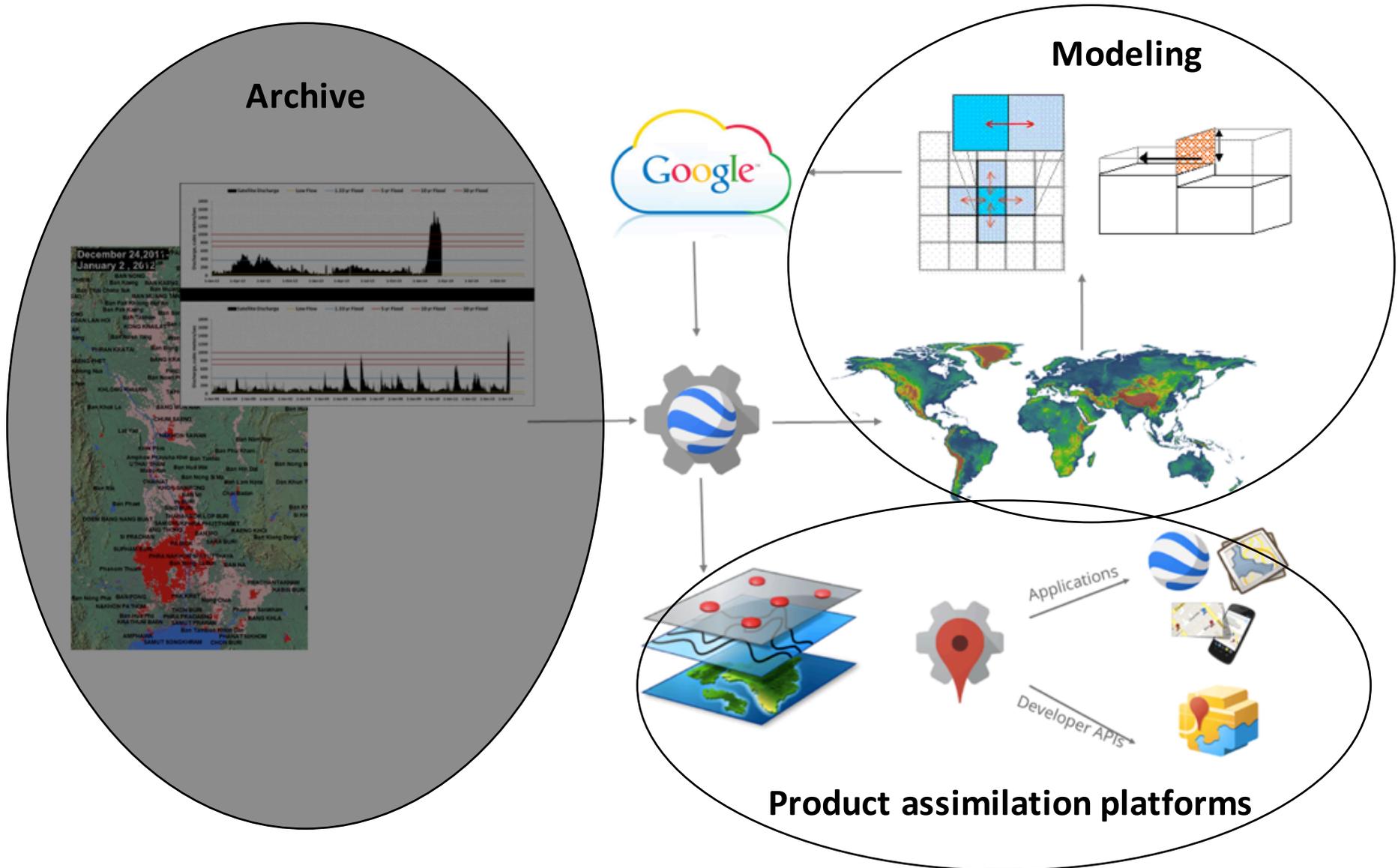


Floodplain within the alluvial plain of the Waimakariri River, New Zealand.

We lack adequate geospatial information on a ***global basis*** defining floodplains within the ***mean annual*** flood limit, or 25 - 50 - 100 year floodplains.

Knowledge of global flood plain dimensions are essential when e.g. assessing the global carbon cycle

Project overview



The Flood Observatory



~2 decades of water related products

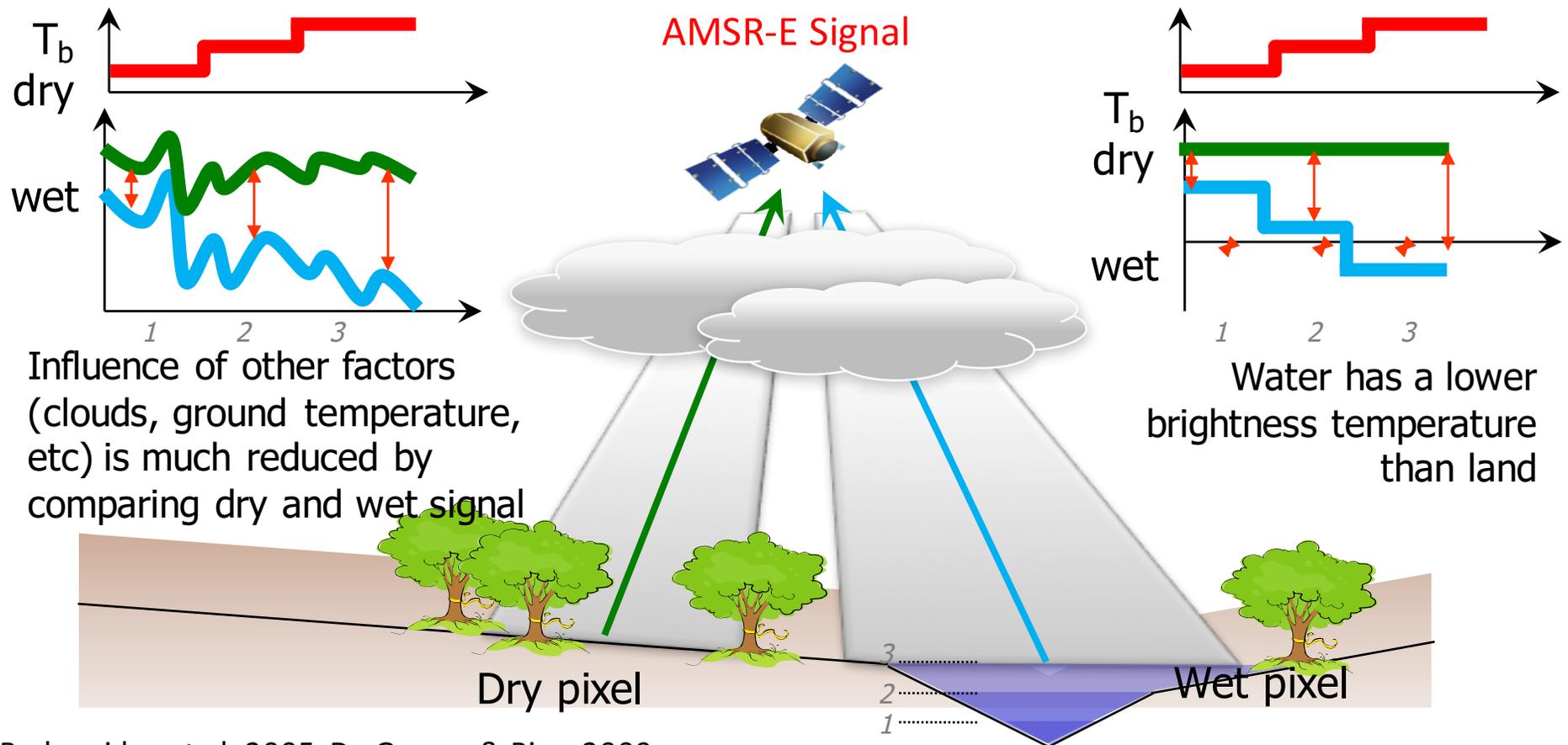
Utilize satellite derived data to provide daily:

- 1) River discharge (AMSR-E/2, Microwave 1998 -> (17yr))
- 2) Flood extents (MODIS, Optical 2000 ->(15yr))

Advances using Satellites:

- a) Daily, global coverage
- b) Consistent use of methods globally
- c) Space based gauging stations monitor also during floods

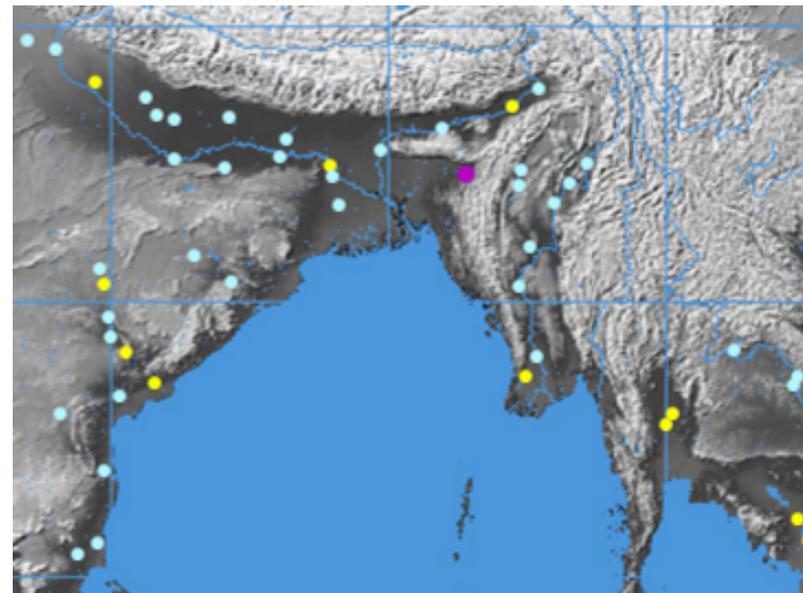
AMSR-E/AMSR-2 River Measurement Method



Brakenridge et al, 2005; De Groeve & Riva, 2009

Cooperative work including EU's **Joint Research Centre** (GDACS, Dr. Tom De Groeve) and DFO has resulted in a **global** network of satellite river gauging sites, with records extending on daily basis from 1998 up to today. Online display (click on dots).

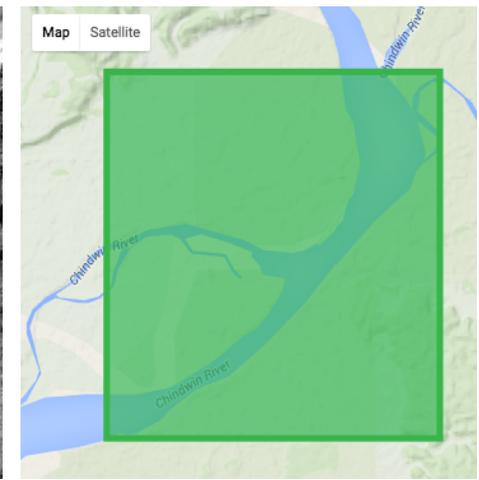
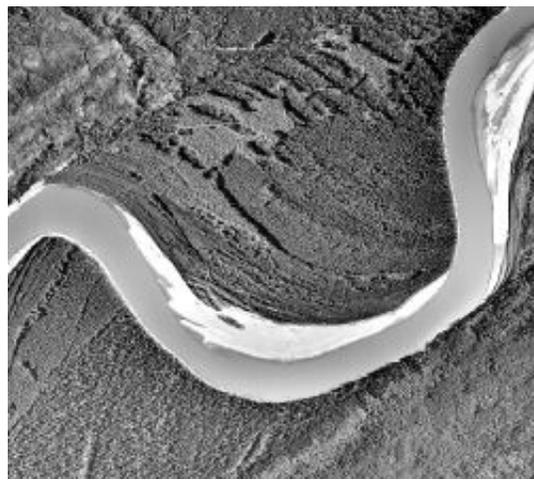
- Low flow
- Normal Flow
- Moderate Flooding, $r > 1.33$ years
- Major Flooding, $r > 5$ years



$$Q = \text{Width} \times \text{Depth} \times \text{Velocity}$$

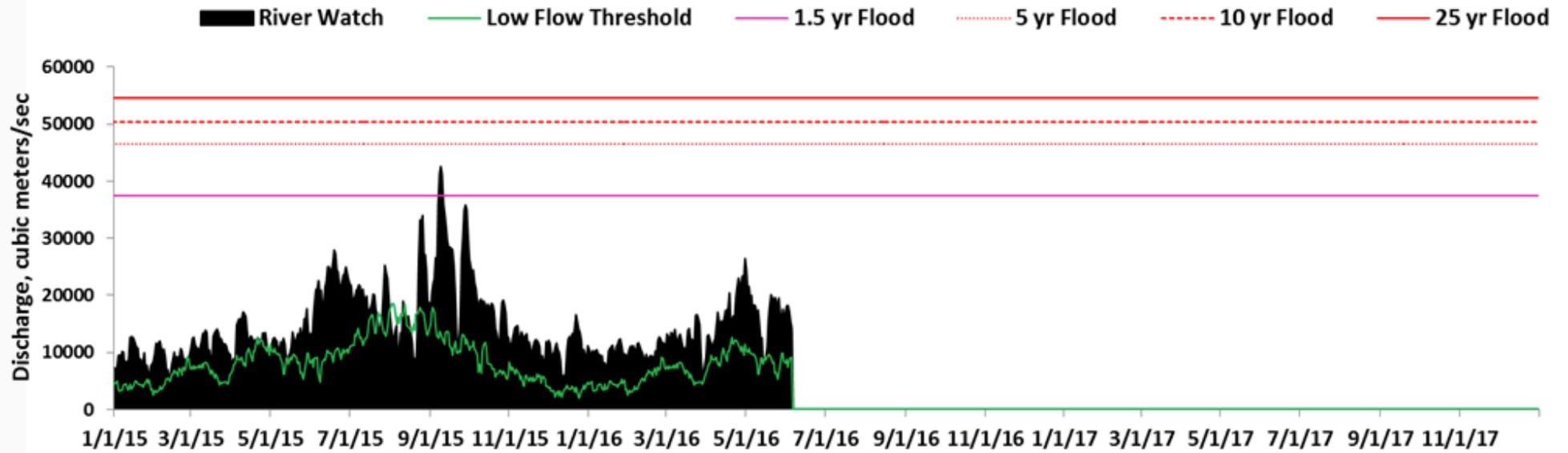
When rivers rise (discharge, Q , m^3/sec , increases), flow width and water surface area also increase.

River Watch sites use satellite passive microwave radiometry to sensitively monitor this in-pixel surface water change.



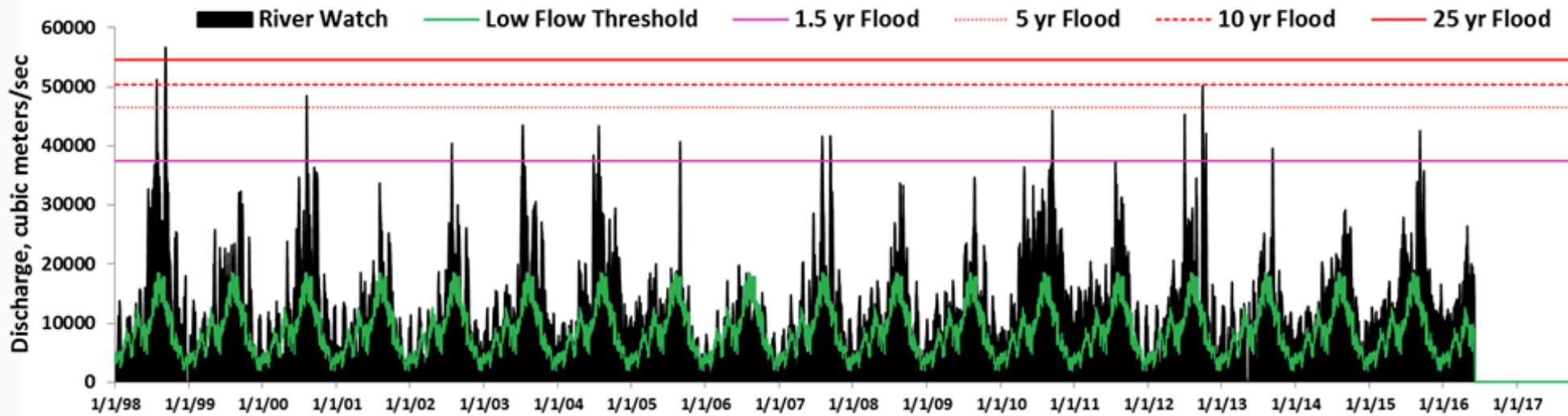
Recent Record

[Technical Summary](#)



Complete record

Low flow threshold is 20th percentile discharge for this day, 2003-2013.

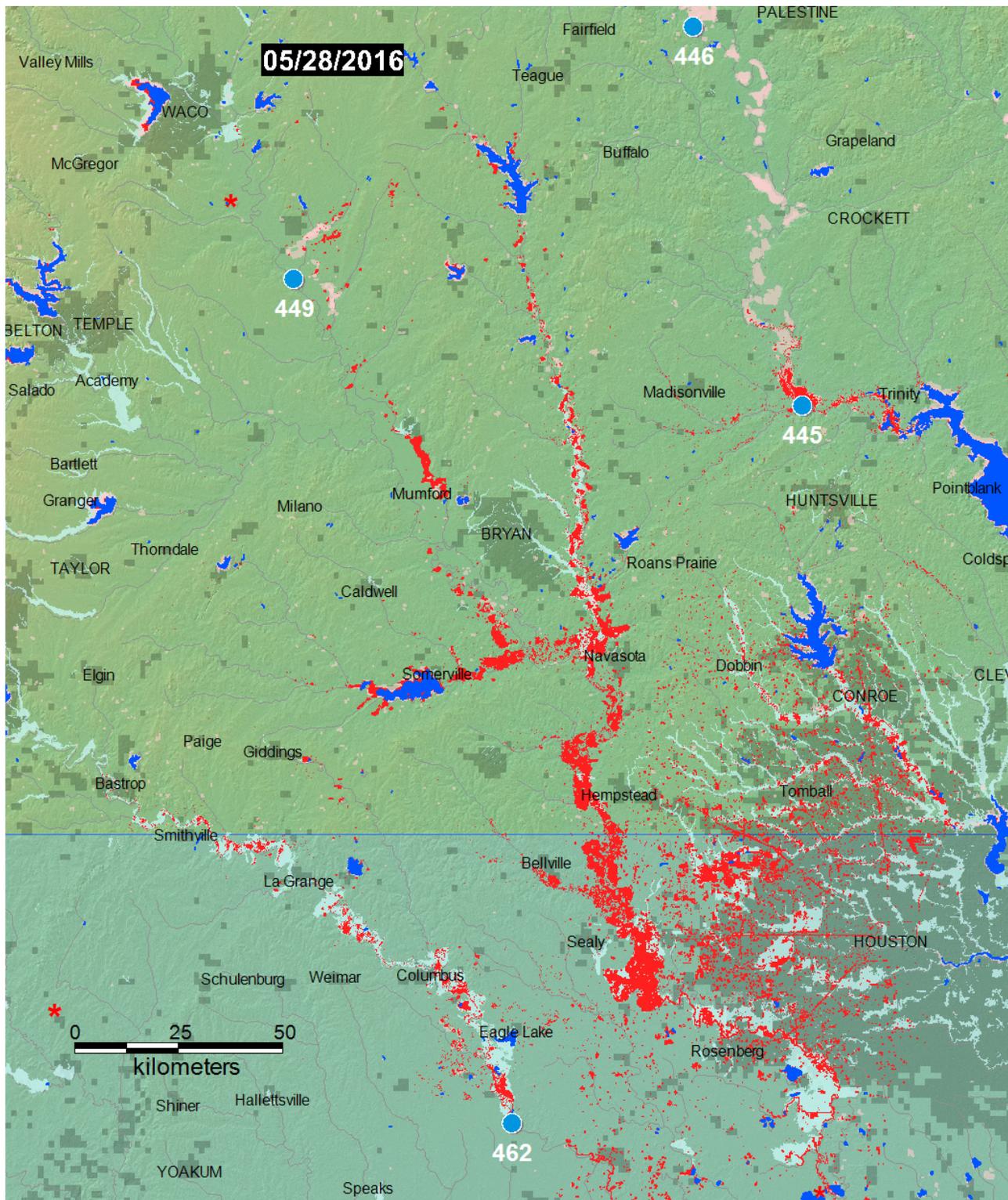


Flood extent measuring method

- Water mapping using NASA's two MODIS sensors (2000 ->)
- Optical bands are used to classify water, applying a ratio $(\text{Band2} + A) / (\text{Band1} + B)$
- NASA Goddard Spaceflight Center has automated this to deliver Near-Real-Time water extents (< 3 hours)

Texas floods

05/28/2016



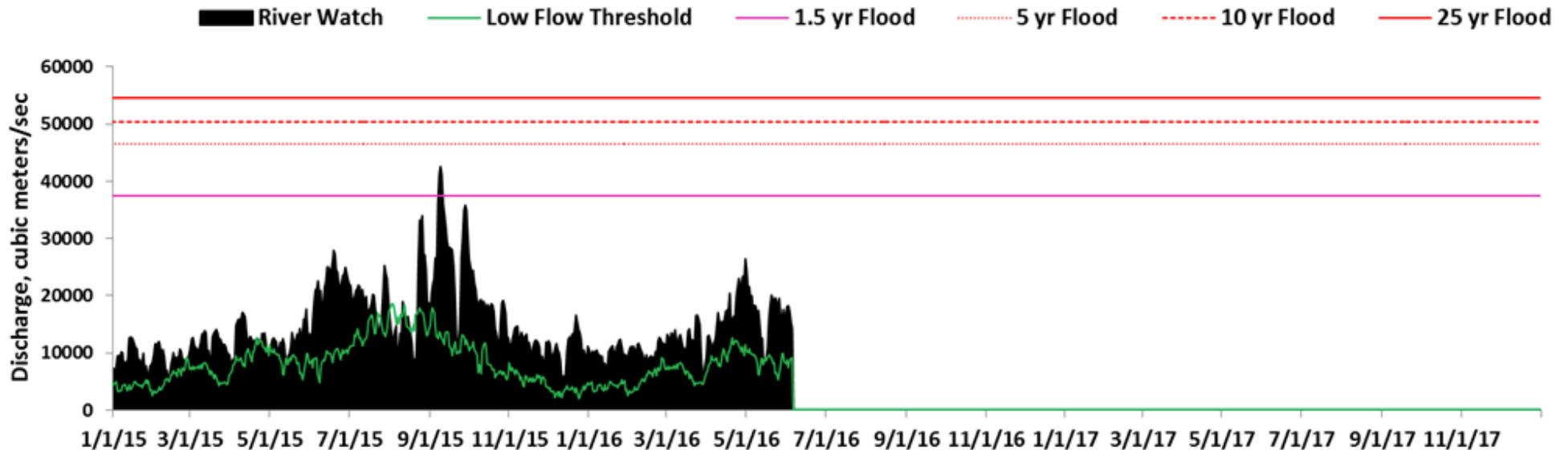
- Red: May 28th flooding
- Blue: Permanent water
- Light blue: FEMA 100yr
- Light red: Previous years observed floods

Combining the discharge information with optical imaging and mapping of flood extent provides a robust way to evaluate new flood severity, on a reach basis.

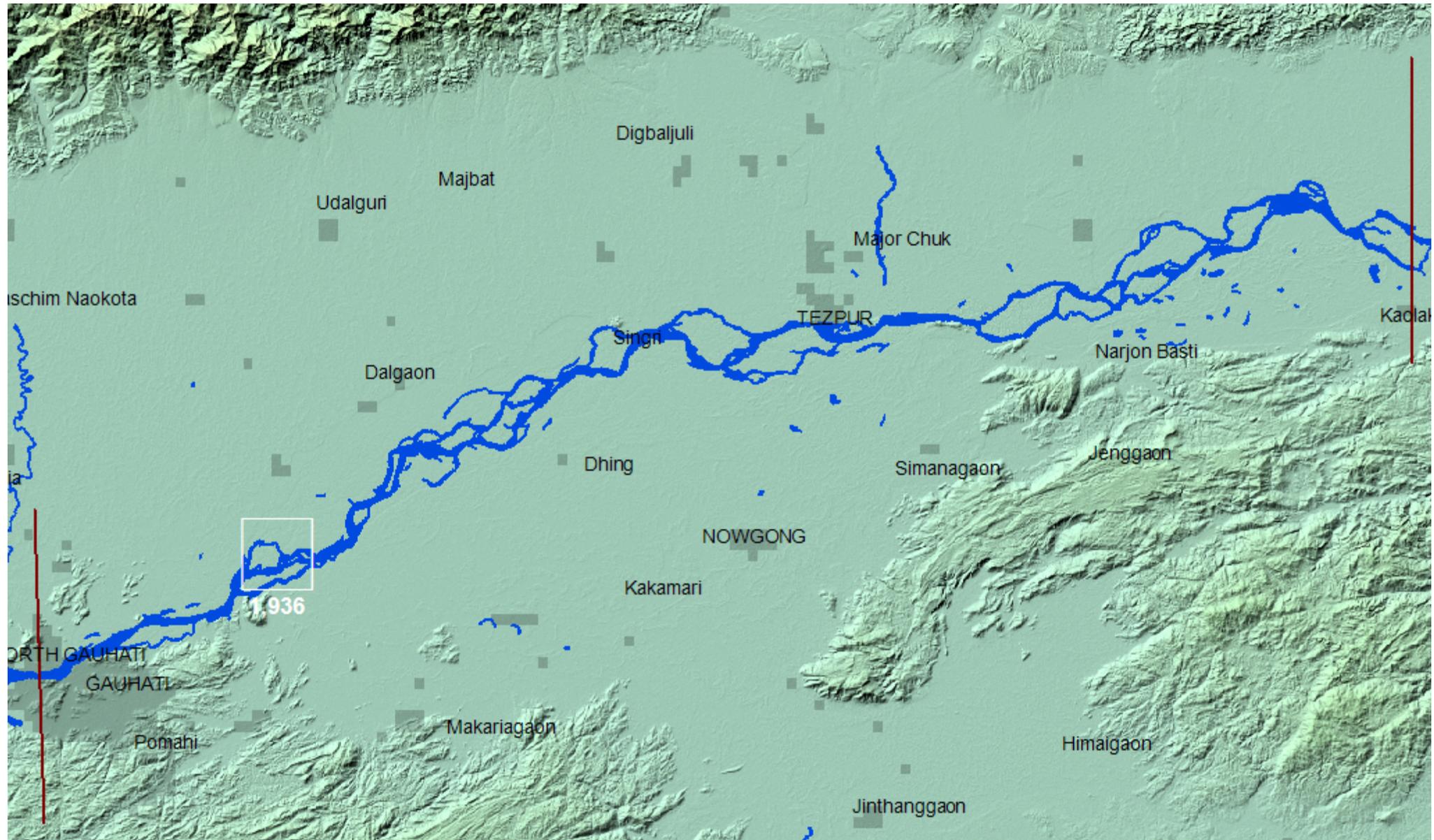


Predicted Flooded Area

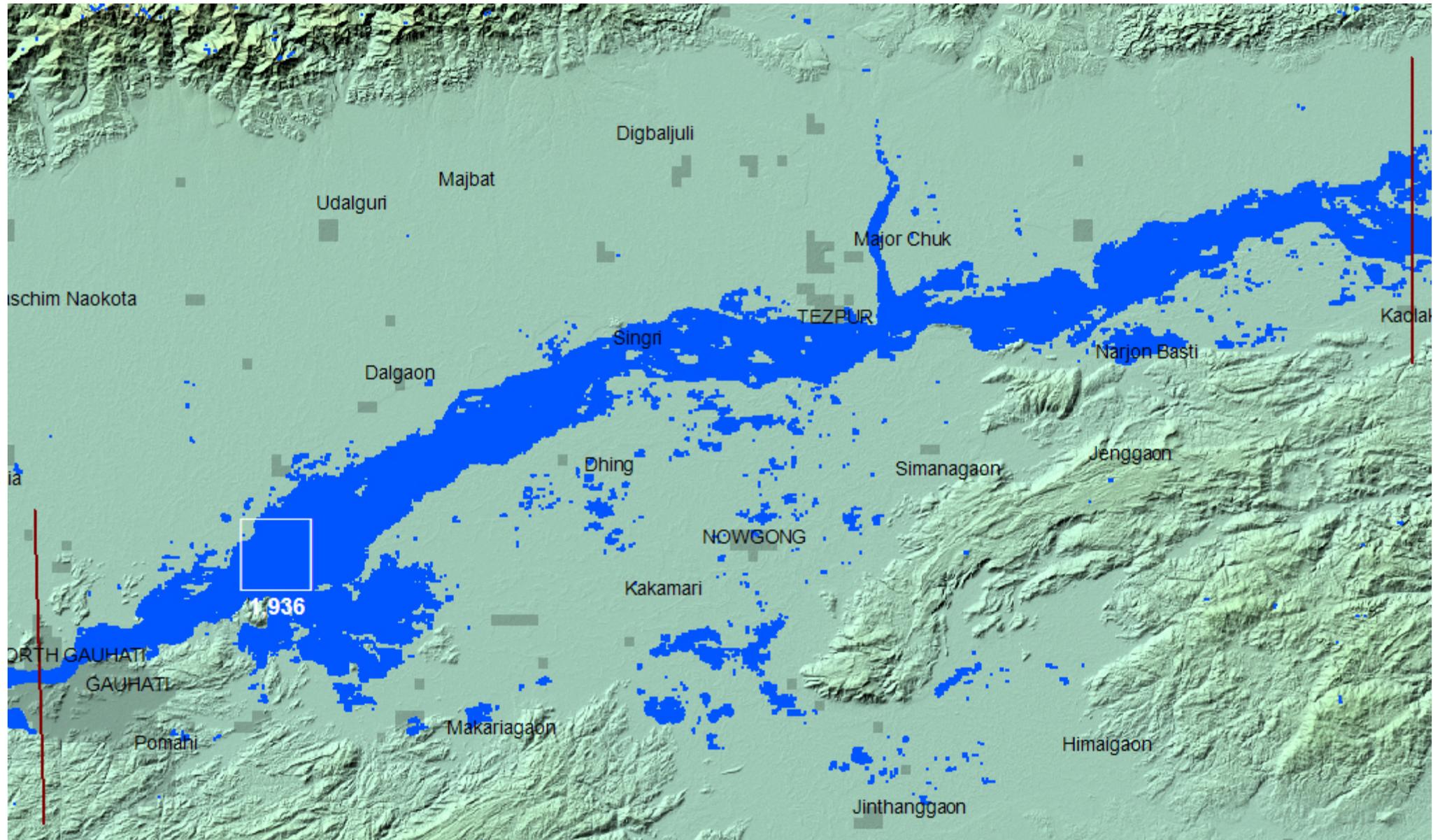
River Watch Gauging Site 1936



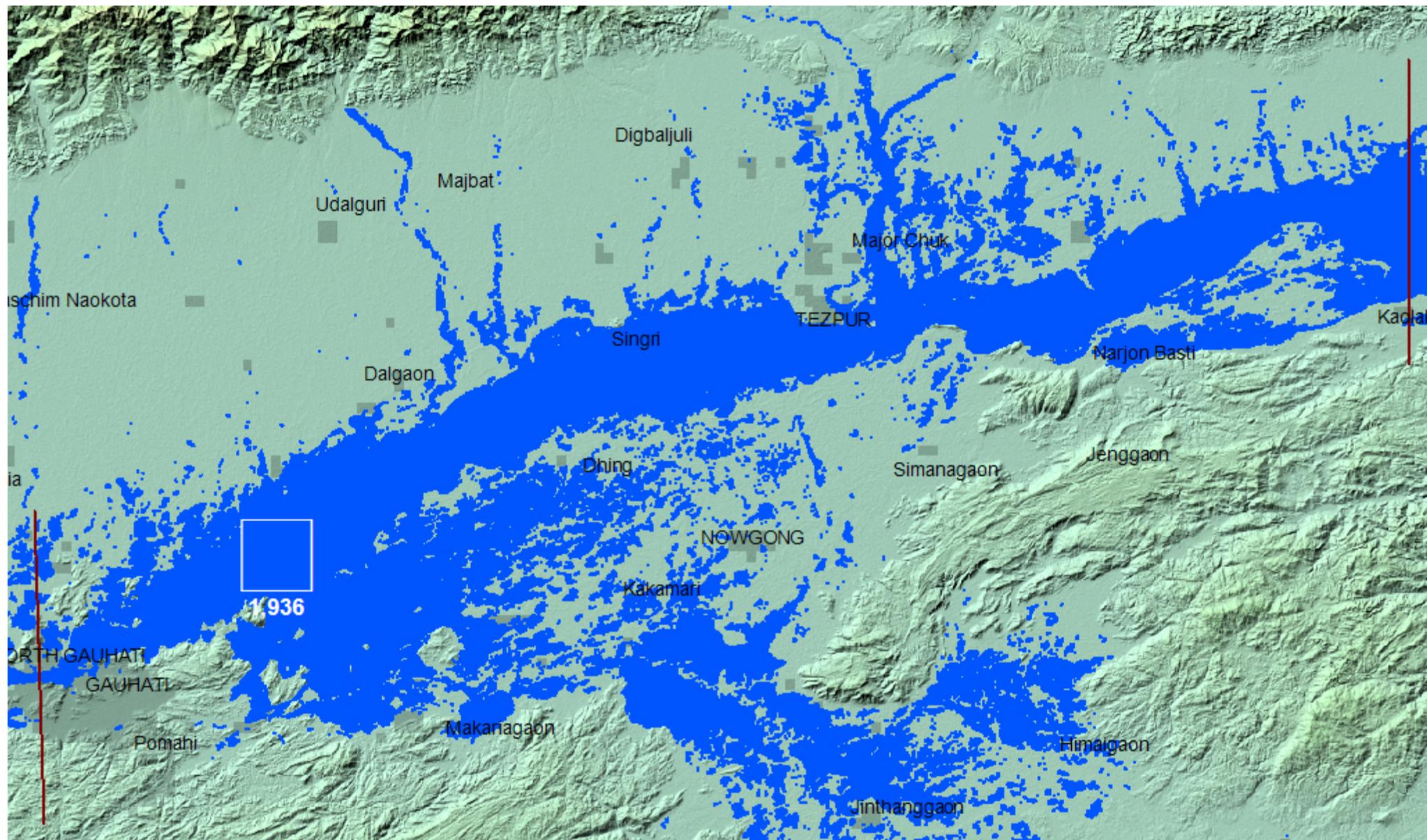
Flooded area for Normal Flow, Winter ($\sim 6100 \text{ m}^3/\text{sec}$, observed February 11-22, 2000)

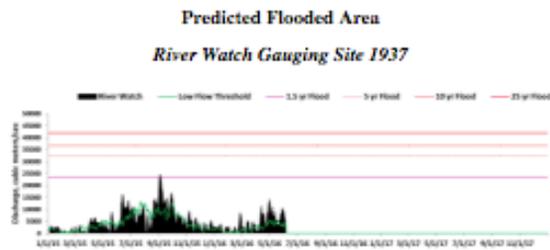


Flooded area for Moderate Flooding, $r = 1.8 \text{ yr}$ ($37,000 \text{ m}^3/\text{s}$, observed summer, 2013)

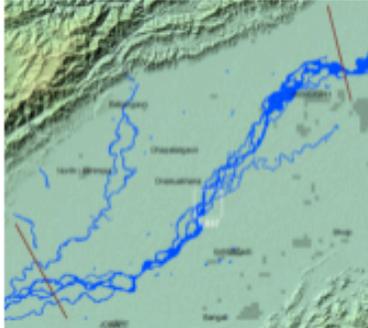


Flooded area for Moderate Flooding, $r = \underline{3}_{yr}$ ($44,000 \text{ m}^3/\text{s}$, observed summer, 2007)





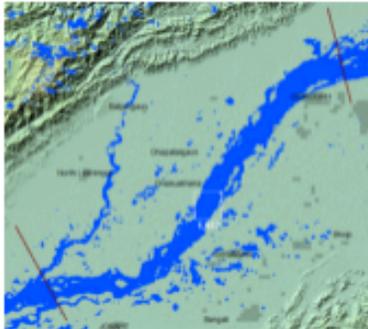
Flooded area for Normal Flow, Winter (~ 240 m³/sec, observed February 11-22, 2000)



[Geotif version](#)

[Google Earth kmz version](#)

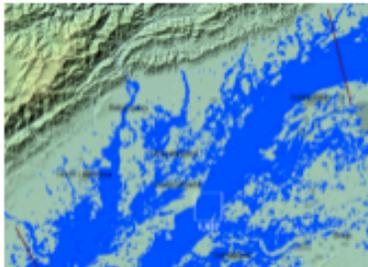
Flooded area for Normal Flow, $r = 1.3$ yr (observed summer, 2013)



[Geotif version](#)

[Google Earth kmz version](#)

Flooded area for Major Flooding, $r = 9$ yr (observed summer, 2007)



DFO mobile-friendly Predicted Flooded Area Displays

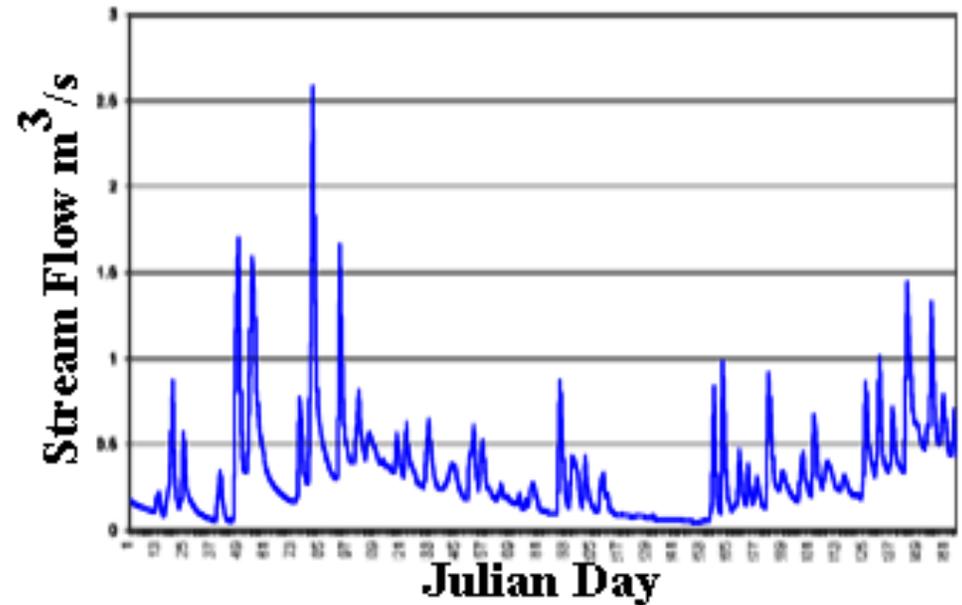
Question: Can satellite information provide accurate information about on-going flooding: its severity, extent, and duration?

Answer: Yes, especially along defined river reaches where both microwave and optical (flood extent) data are available with long time series.

Modeling floods

Water Balance Model (WBM):

Fully coupled global hydrological model that simulates vertical terrestrial and atmospheric water exchange and the horizontal overland water transport along a prescribed river network.



LISFLOOD-FP: Two-dimensional flood inundation modelling.

Uses gridded discharges to estimate inundated area.

In this study, **LISFLOOD_FP** will ingest **WBM** discharges to estimate inundated area.

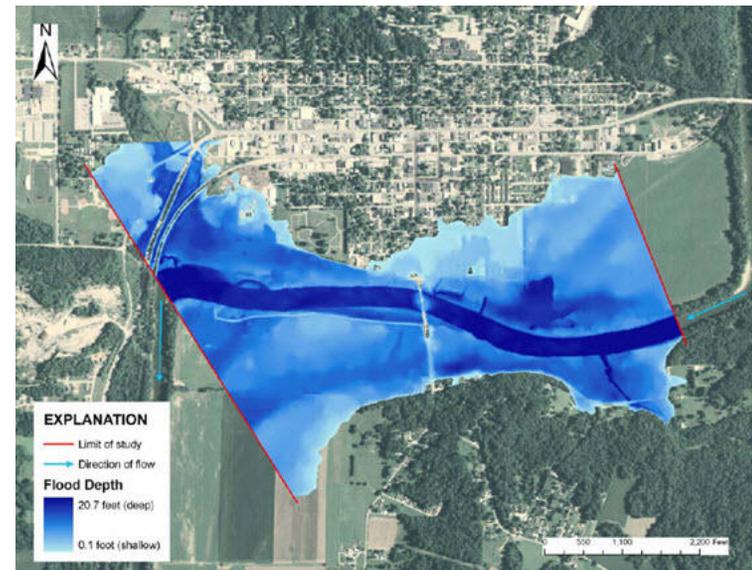
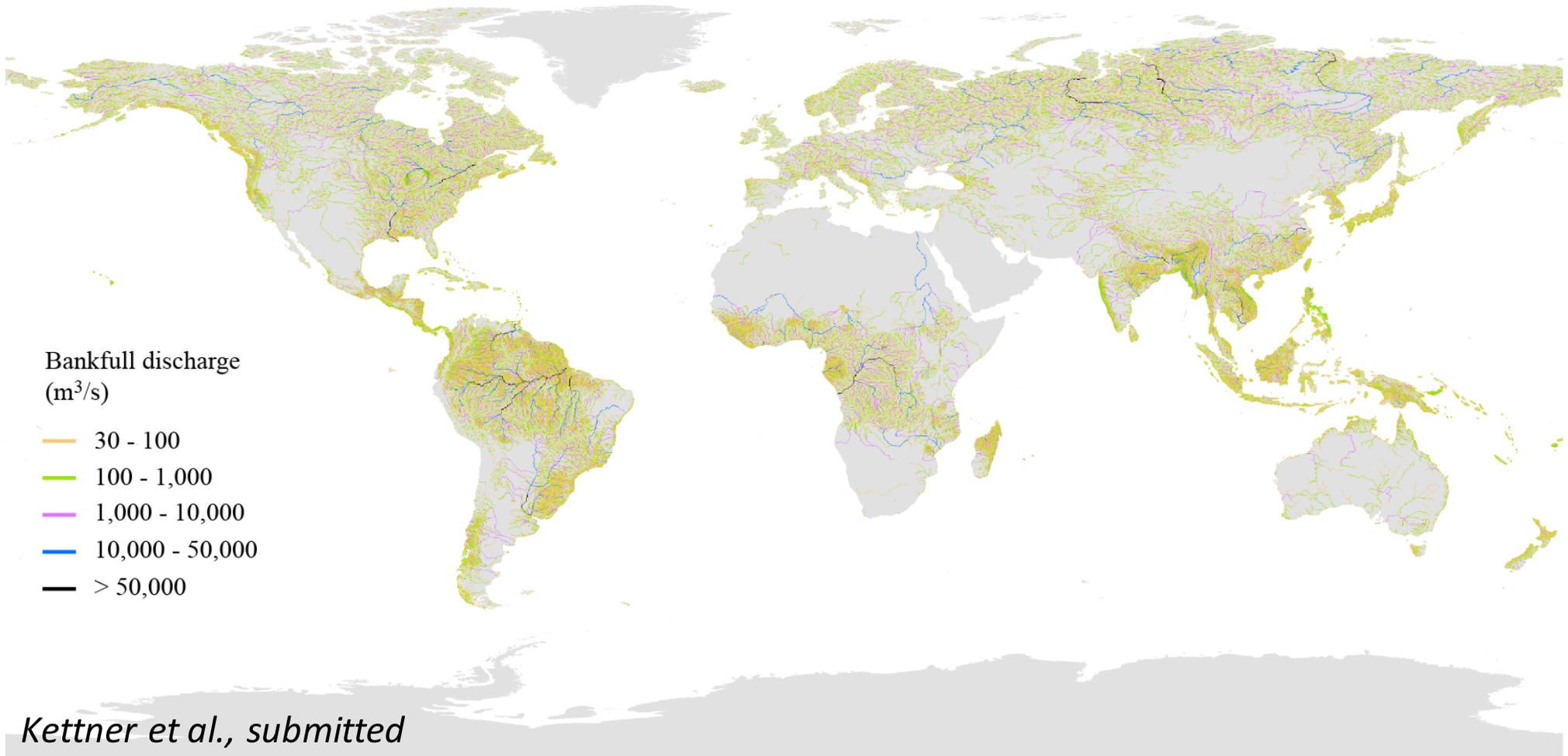


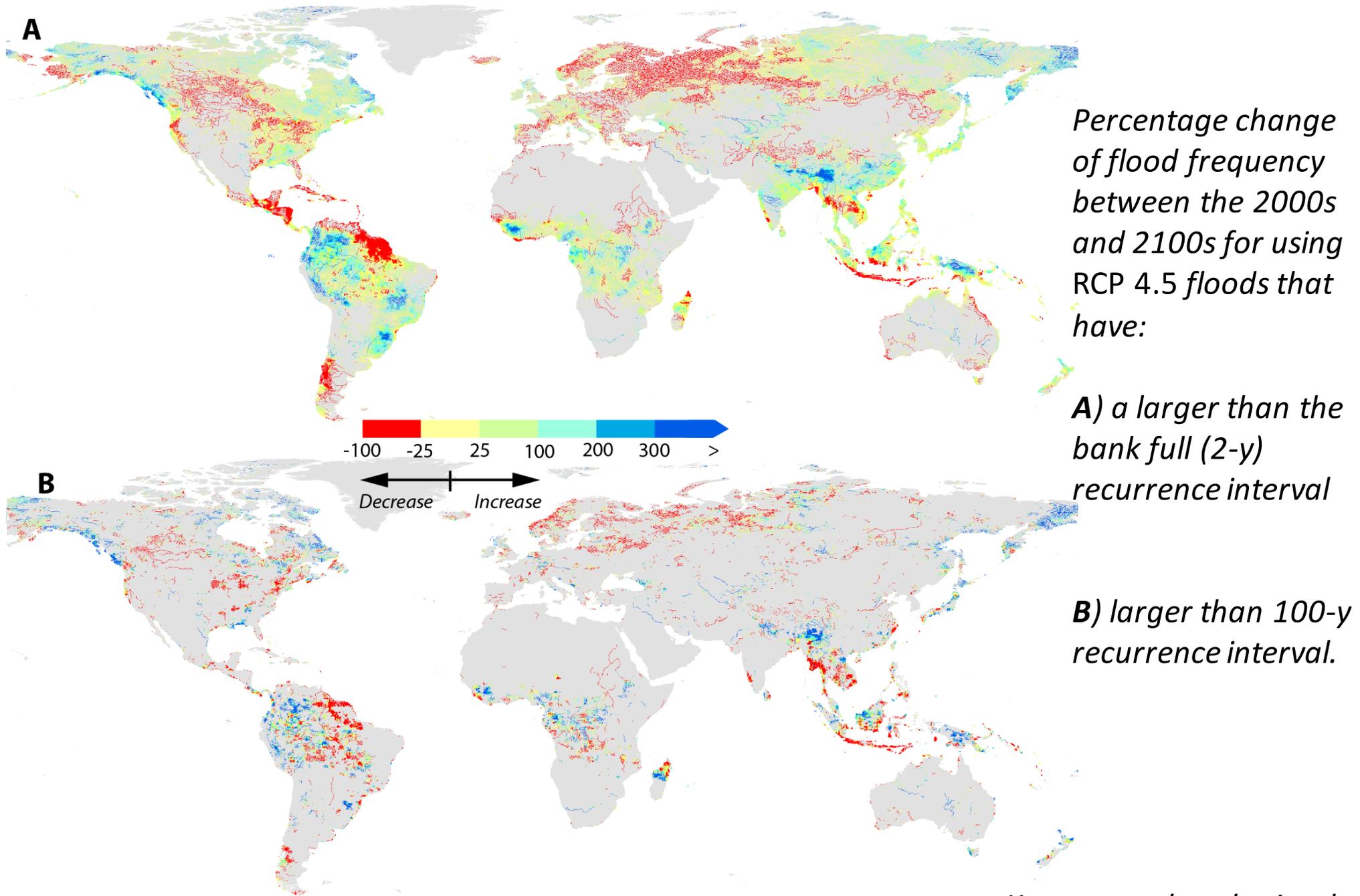
Image from USGS, flood mapping example

WBM: Bank full discharge



Log-Pearson to estimate water discharge recurrence intervals for 30 year daily discharge

WBM: discharge changes over time



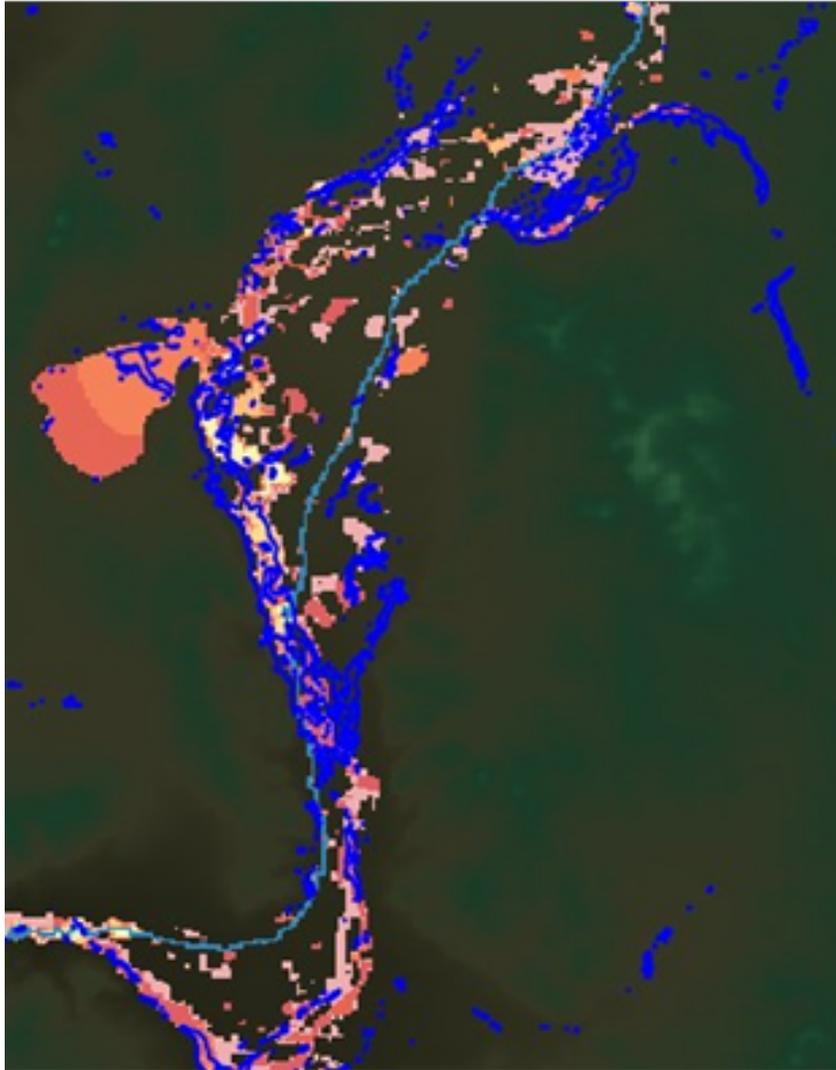
WBM: Percentage change in flood frequency, comparing 2000s – 2100s

Continent	Percentage change in flood frequency per recurrence interval (years)				
	5 - 10	10 - 25	25 - 50	50 - 100	100 - 200
Africa	42	70	106	152	182
Asia	74	106	144	180	219
Australia	46	67	106	176	302
Europe	-22	-8	14	27	39
North America	30	74	131	174	229
South America	80	126	176	227	261
World	52	87	130	169	208

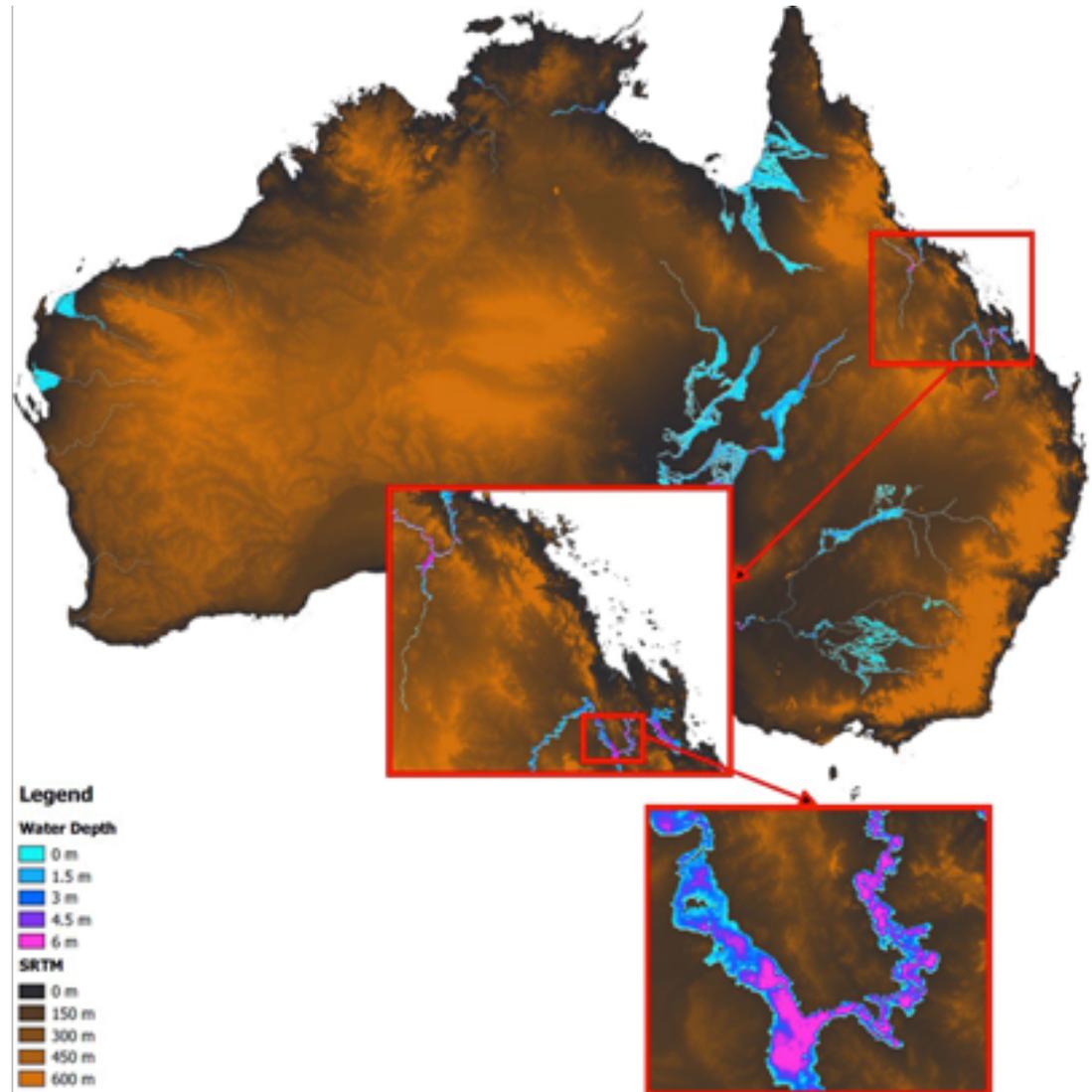
Kettner et al., submitted

LISFLOOD-FP, Case 1 of 3: Australia

- First full continent simulated (40 years gauged daily streamflow: 1973-2012)
- Evaporation & reservoirs (non-operational) included
- Calibrated (gauged water level & historic Landsat flood image in MDB) & Validated (using Landsat 1987-2014 water mask over a 17k sqkm area)

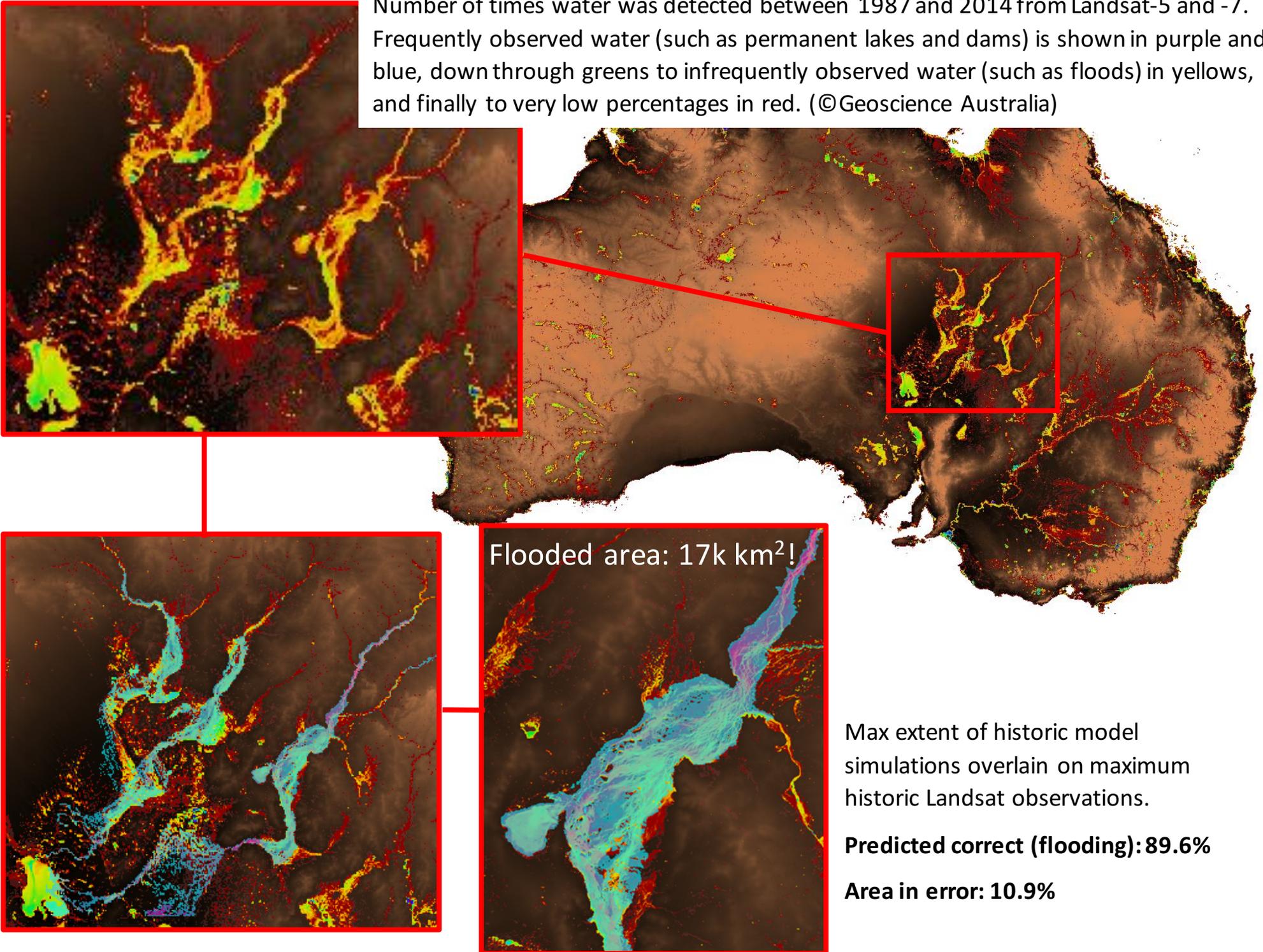


Frequency of inundation map of LISFLOOD-FP over 40-years (1973-2012). The map shows in **light pink** approximately a **1:10 year** inundation and in **darker pink** a **1:40 year** inundation. The **flood extent in blue** is a **MODIS** imaged event in early 2011 (according to the fit, may indicate approximately a 1:30 year event)



Translating the 1 km model results onto the 90 m SRTM-DEM

Number of times water was detected between 1987 and 2014 from Landsat-5 and -7. Frequently observed water (such as permanent lakes and dams) is shown in purple and blue, down through greens to infrequently observed water (such as floods) in yellows, and finally to very low percentages in red. (©Geoscience Australia)



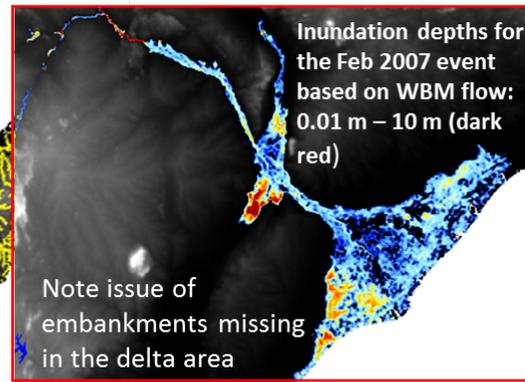
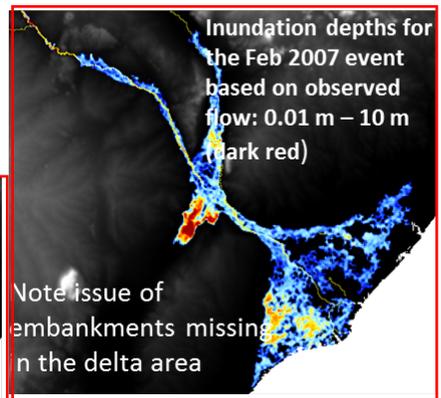
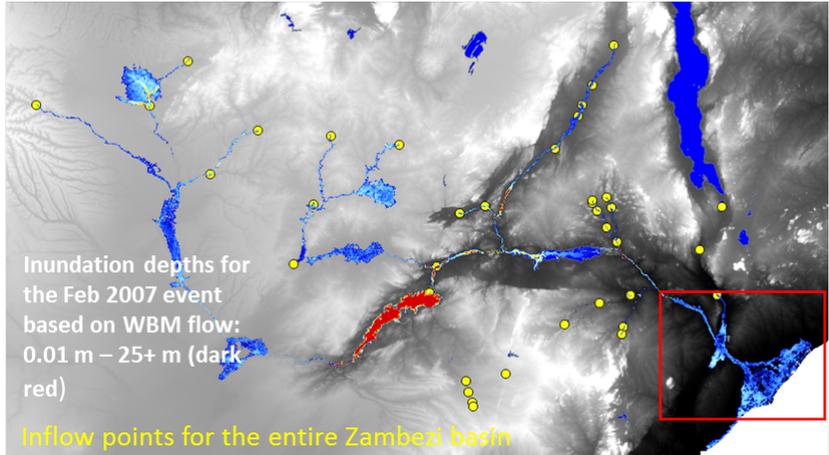
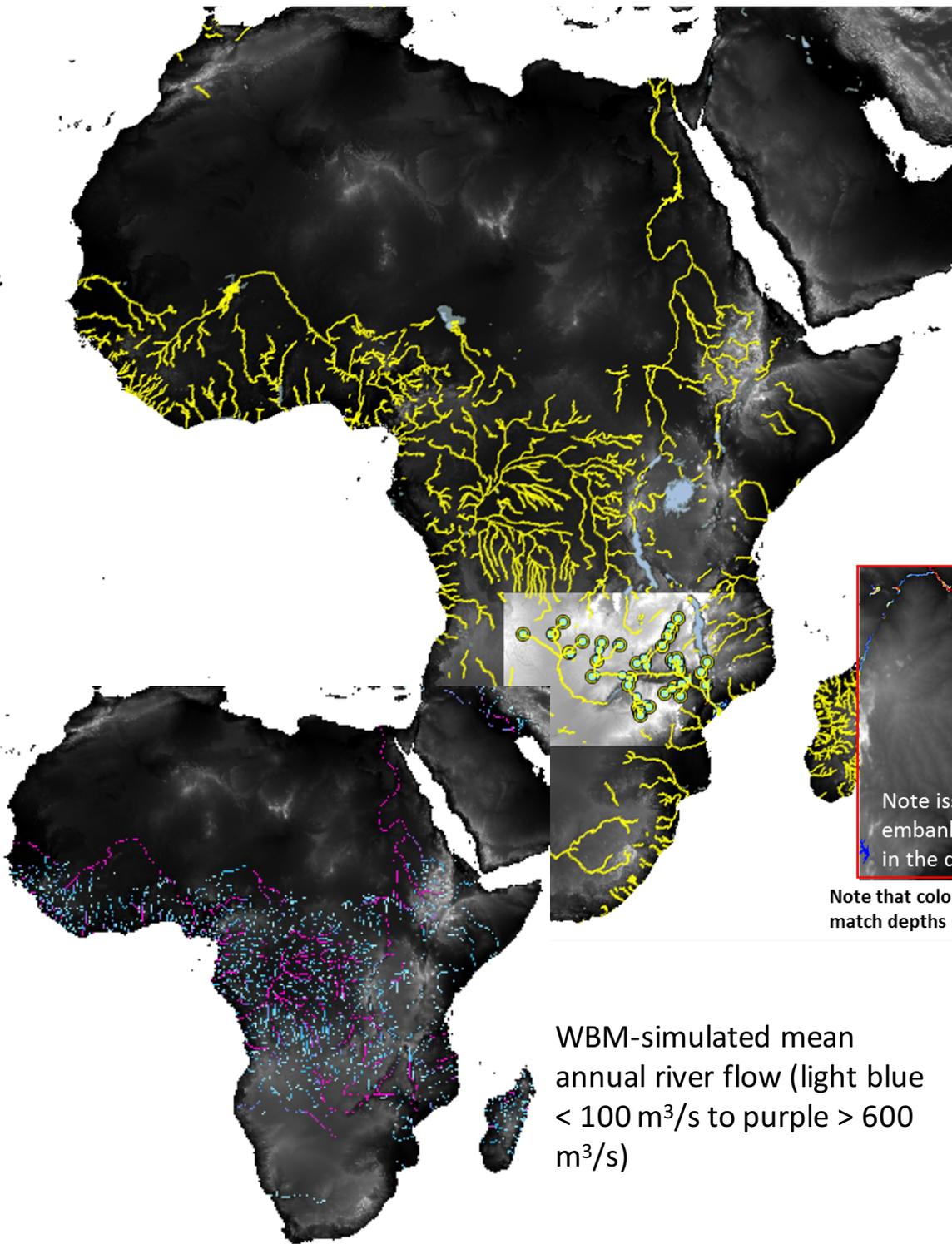
Max extent of historic model simulations overlain on maximum historic Landsat observations.

Predicted correct (flooding): 89.6%

Area in error: 10.9%

LISFLOOD-FP, Case 2 of 3: Africa

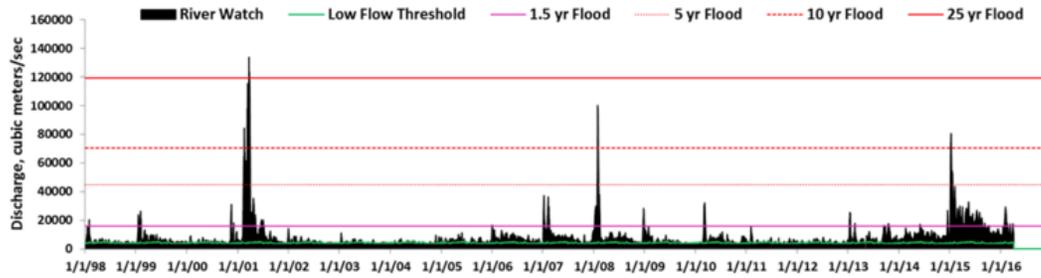
- Complex topography & vegetation
- River network much denser than Australia
- Many reservoirs in basins that are important
- No gauging information, so use of WBM hydrology model to simulate historic event flows (~50 years of daily discharge)
- No good stream network data -> need to use Landsat-derived network
- Data volume is large -> need to consider storage facilities and online analysis platforms such as EE, and cloud computing
- Integrate fully with DFO data (many captured events)



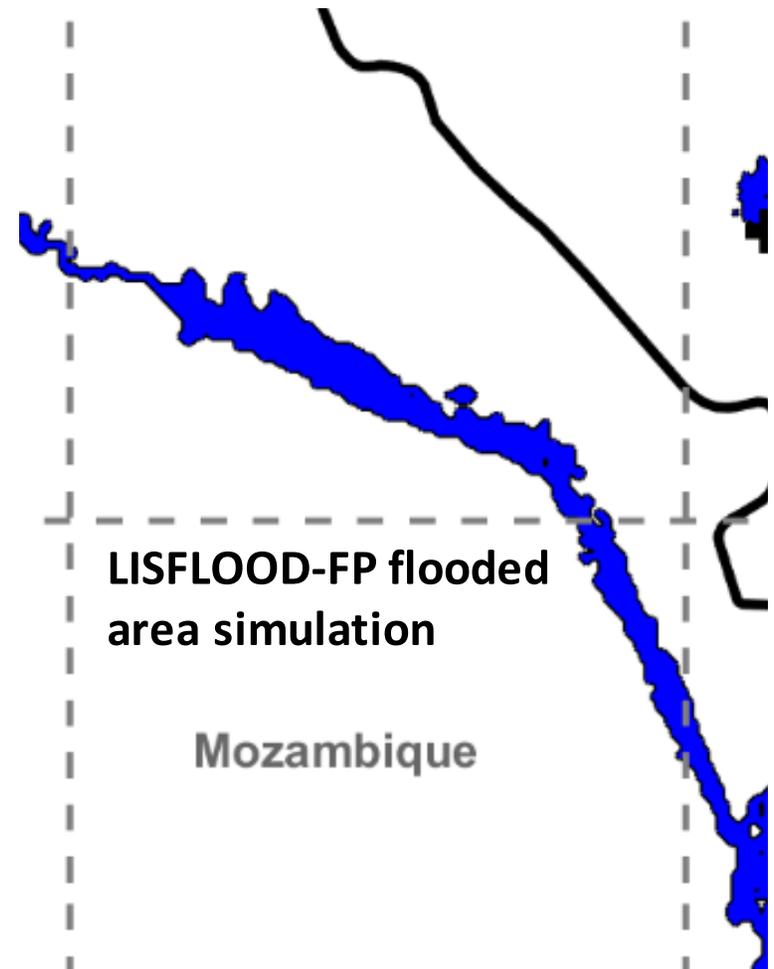
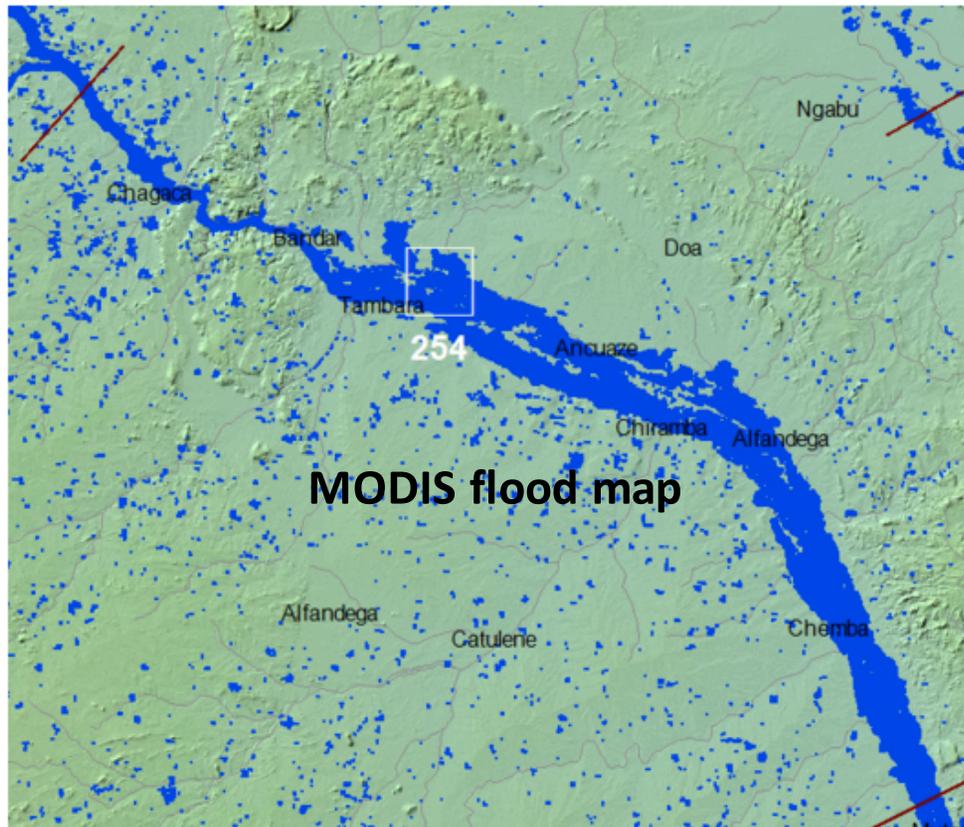
Note that color is rescaled for Lower Zambezi zoom-in area to match depths color in observed flow simulation (right)

WBM-simulated mean annual river flow (light blue < 100 m³/s to purple > 600 m³/s)

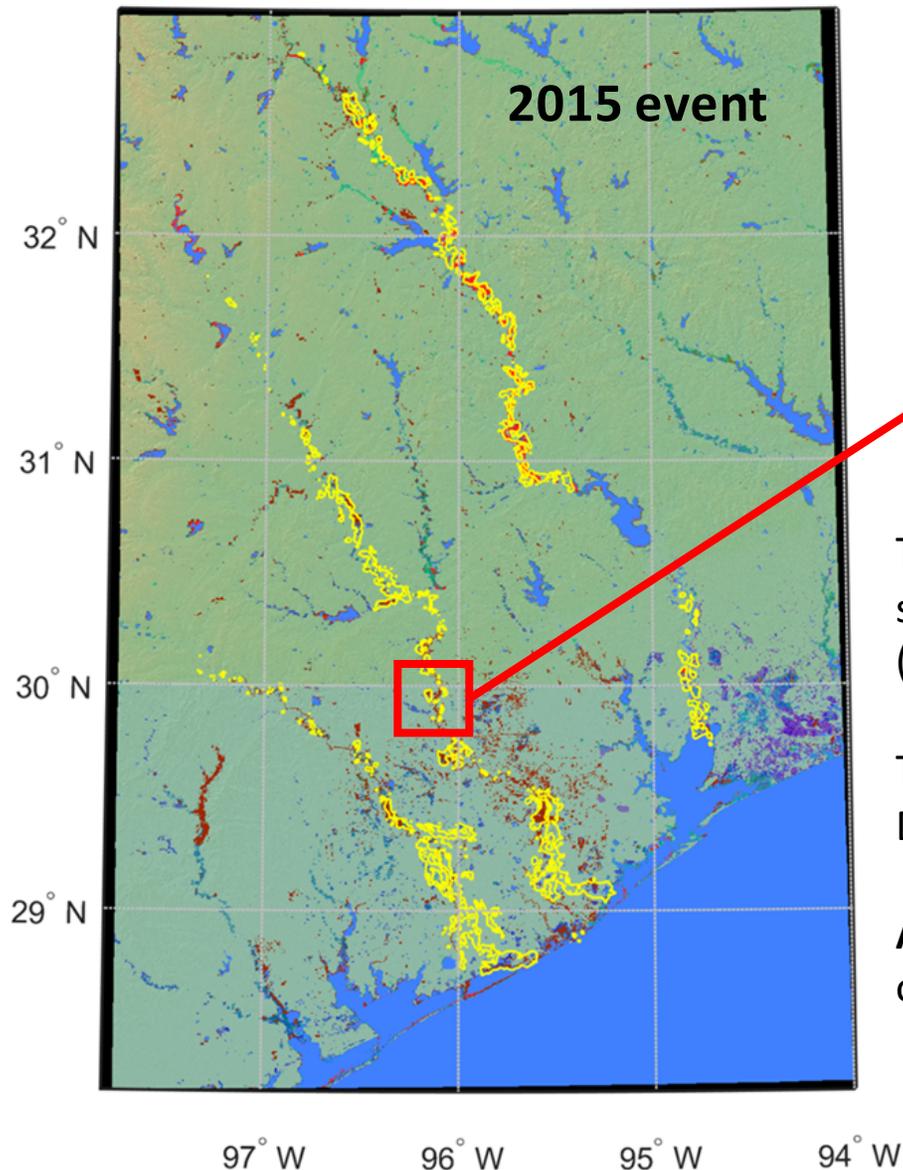
Africa Supersite: MODIS flood map vs. flood model (2008 event):



Flooded area for "4", Major Flooding, $r = 18$ yr (observed 2008)



CONUS: Texas Supersite Case 3 of 3



Texas May/June 2015 event (left): yellow outline model simulation (yellow outline) overlain on satellite flood maps (Landsat & Sentinel, COSMO-SkyMed (CSK))

Texas May/June 2016 event (zoom-in on right): Landsat-8 DFO flood map, again same location, along the Brazos

Aim: Assimilate all these model & Earth Observation data over Texas

Project summary

Hydrological archive

- DFO: Setup server to make flood archive better accessible.
- DFO: Developed a combined product to show the extent of inundated area per discharge events for a given area of interest.

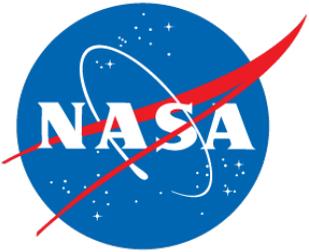
Modeling

- WBM: Developed a global gridded layer of bankfull, 25, 50, 100, 200 year recurrence interval water discharges
- LISFLOOD-FP: Developed first inundated layers for various case studies some at the continental level

Future work

- Start a more rigid validation of LISFLOOD-FP for bank full water discharges and other recurrence interval water discharges
- Apply LISFLOOD-FP at continental scale to e.g. NA, Africa
- Utilize google product assimilation platforms

Thank you!



2 year AIST funding